Online monitoring of the impact of language processing on motor processes: Prehensile grip-force measures during passive listening of manual action words and sentences.

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INTRODUCTION

Behavioural studies have established that processing linguistic descriptions of motor actions affect overt motor behaviour. Yet, the fact that behavioural paradigms typically capture language-induced motor effects at latencies that are beyond latencies for **lexical access** is frequently used to challenge this assumption. The development of simpler techniques adapted for measuring online motor-language interaction is needed. In the present study we aim to introduce a novel experimental tool, a **grip-force sensor** (ATI mini-40) that allows **online measures** of the effects of language processing on motor behaviour.

METHODS

Participants

Participants were French undergraduate students (Mean age= 20.6 years; range: 18 to 35 years) . All participants were right-handed as defined by the Edinburgh Inventory (Oldfield, 1971) with normal hearing and no reported history of psychiatric or neurological disease. Twenty-three subjects (11 females) participated in **Study 1**, and seven-teen (9 females) in **Study 2.**

Apparatus

In order to quantify online measures of subtle grip force modulation, we used a grip-force sensor (ATI mini-40) with a 3-axis load cell (see Figure 1).

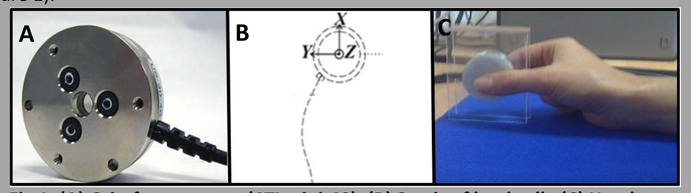

Fig 1: (A) Grip-force sensor (ATI mini-40). (B) 3-axis of load cell. (C) Hand position throughout the experiment.

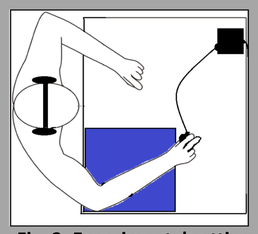

Fig. 2: Experimental setting

Procedure

Participants were asked to hold the grip-force sensor with their right hand (the thumb, index and middle fingers rest on the load cell throughout the experiment) (see Figure 1 and 2).

In **Study 1** participants' **listen passively** to spoken sentences that contained action or non-action target words. In **Study 2** action words were additionally presented within **affirmative** or **negative sentences** (see table 1). Participants' task was to silently count how many sentences contained the name of a country.

In both studies, action or non-action target words were also presented without sentence context as a list of single words. Here, participants were requested to simply count how often a pre-determined target word occurred in the list.

Stimuli

A total of 115 French sentences served as stimuli (see Table 1). Ten of these sentences contained the name of a country. The remaining 105 critical sentences contained either one of 35 target-nouns or one of 35 target-verbs, controlled for frequency, number of letters, number of syllables, bi- and trigram frequency. All verbs denote actions performed with the hand or arm (e.g., scratch, throw) while nouns referred to concrete entities without specific motor associations. The 35 target-verbs were embedded in affirmative as well as negative context.

Category	Sentence
Affirmative Action Sentence (Study 1 and 2)	Dans la salle de sport, Fiona soulève des haltères
Negative Action Sentence (Study 2)	A l'intérieur de l'avion, Laure ne soulève pas son bagage
Non Action Sentence (Study 1 and 2)	Dans la montagne, Léonard voit l'aigle qui plane

Table 1. Example of stimuli used in the experiment

References

Tettamanti, M., Manenti, R., Della Rosa, P. A., Falini, A., Perani, D., Cappa, S. F., and Moro, A. 2008. Negation in the brain: modulating action representations. *Neuroimage* 43, 358–367

Tomasino, B., P.H. Weiss, and G.R. Fink. 2010. To Move or Not to Move: Imperatives Modulate Action-related Verb Processing in the Motor System. *Neuroscience* 169, no. 1: 246-258. Academic Search Premier, EBSCOhost

RESULTS

Study 1 : Exploratory Data Analysis

The Study 1 was used to determine the time window within which differences in grip-force between action and non-action words and sentences became significant: A paired one-tailed t-test (by millisecond) from 0ms to 800ms after critical word onset was performed. In sentence context continuous significant differences were observed between 270-500 ms after stimulus onset. For isolated words, this window ranged from 188-272 ms.

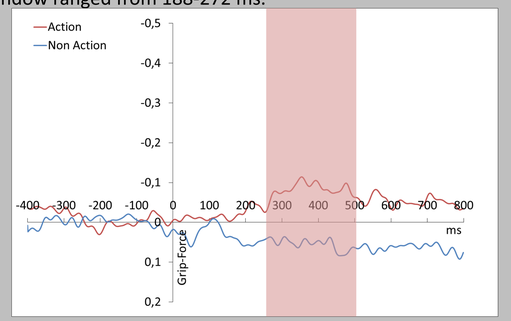

Fig. 3: Time-window of significant differences between Grip-Force amplitudes for Action and Non-Action Sentences.

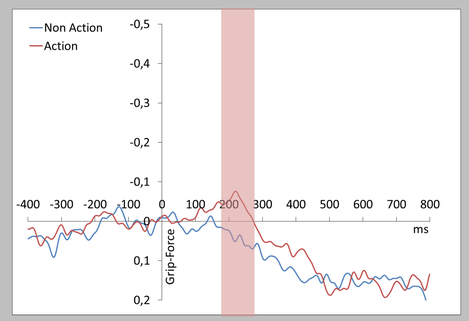

Fig. 4: Time-window of significant differences between Grip-Force amplitudes for Action and Non-Action single Words.

Study 2 : Sentences

Analysis of Variance (ANOVA) over the previously defined time window revealed a significant effect of target word condition [F (2,32) = 4.55; p<0.02]. Post hoc comparison yield significant differences between Affirmative Action vs Non Action (p<0.02); Affirmative Action vs Negative Action (p<0.04). No differences between Negative Action and No Action were obtained (p=0.5). Hence, Grip-force amplitude was enhanced when listening to affirmative action sentence only (see Fig. 5).

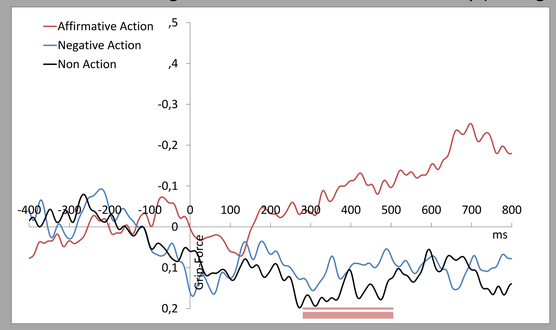

Fig. 5: Action Sentence and sentence Polarity Effects

Study 2 : Single Words

Significant differences between Action vs Non Action words [F (1,14) = 5.31; p<0.04] were observed in the previously defined time window of 188-272 ms after onset. Grip force amplitude was enhanced by action words compared to non-action words (see Fig. 6).

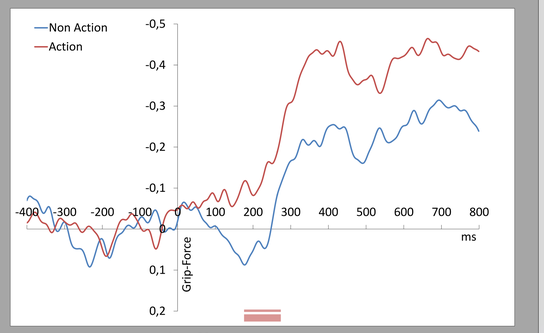

Fig. 5: Action words Effect.

CONCLUSIONS

The greater force observed during manual action verb processing suggests that language-induced motor activity can involve **later states of a motor performance**, recruiting cortico-spinal circuits as well as muscular fibres. Indeed, passive listening was sufficient to detect partial activation of executive stages of a motor performance pattern, although no motor task associated to the linguistic process was required. To our knowledge, this is the first time that a demonstration of this phenomenon is made.

Crucially, we have observed that action sentence polarity (negative or affirmative) had an effect on the grip-force since negative sentences did not increase grip force amplitude, suggesting that sentential **negation might affect the recruitment of motor representations** of the negated action (see also Tetamantti et al., 2008; Tomasino et al., 2010).

Overall, these findings demonstrate that this novel experimental paradigm can be profitably used to study the online processing of the interaction between the motor system and language in a very simple and ecological manner. More important, we propose this novel technique as an **online monitoring-tool** for elucidating new aspects of the interplay between motor and linguistic systems.